SOME SUGGESTIONS ON THE MAINTAINING FORCES OF COSMICAL MOTION.

By Walter H. Lowrie.

I desire to submit for consideration some suggestions tending to the production of a true theory of the force by which the revolutions of the planets are maintained against the tendency of attraction to draw all bodies to a common centre, or a solution of what Sir John Herschel calls "the theorem" of the conservation of the *vis viva* of cosmical motion.

I know of none hitherto received except that composed of the postulate of an original impulse and the law of inertia: that a body set in motion by a single impulse and out of relation with other bodies moves forever with its initial velocity and direction. Such a proposition is evidently not a product of induction, for no body was ever known to be in such a case or to move thus; and therefore it defines no actual class of motions whatever, as every physical law ought to do. Indeed philosophy never treats of things out of their relations. This is, therefore, a mere metaphysical idea, meaning only this, that, in the investigation of motions so as to find their system, the mind demands a cause for every change in their degree or direction.

It very properly assumes an original propulsion; because motion exists, and its origin could not possibly be a matter of human observation. But the theory founded on this law goes beyond the law, and treats of bodies that are *in* relation with each other, and then assumes, that, by reason of this relation, that is, by the attraction of a primary body upon its secondary, motion may be changed in direction without being changed in degree; and thus, according to it, the original propulsion is the true motive power of all cosmical systems, while the only function of attraction is to deflect tangential into elliptical motion and hold it there.

Now this theory is both logically and philosophically vicious; because it takes our idea of absolute motion and uses it as a true expression or law of relative motion; and because, while treating attraction as deflective of tangential motion, it overlooks the question, that it may also retard and suppress it, and thus it treats this force as absolute in degree while relative in direction.

An idea or rule that is absolute in its character can tell us nothing about actual things, though it may regulate our mode of thinking about them. In this instance it bids us seek a cause which maintains cosmical motion against the centralizing force of attraction. We must seek it in this cosmos, just as it is, with its countless bodies, all moving in harmony and yet with countless forms and degrees of motion.

It is impossible to find it in a single initial impulse given at the start of the motion; because the force of attraction of each body on the others would everywhere affect the motion thus given, deflecting, retarding, accelerating, reversing and finally absorbing it, without its having any capacity, as a *vis viva*, of recovering itself. The initial impulse once

given, becomes, as a cause, past and ended, and its assumed effect is uniform velocity forever; but it does not assume to resist the retarding, accelerating and other disturbances that assail the body, and it is impossible that it can do so. Nor can it resist the attraction of its central body, which is constant in its direction, and also in its degree so long as the distance is unchanged. A force that interferes to deflect a moving body must thereby decrease its velocity, and the more direct the interference the greater is this decrease, as a direct one may stop it altogether.

In order to get a clear conception of some of these retardations and accelerations, it is necessary to get beyond the motion of each body, in so far as it is merely relative to its primary, and consider it in a more absolute way. Take the moon in its revolution round the earth, starting with it at its first quadrature. Then it is 240,000 miles in the rear of the earth. It must of course overtake the earth, as it does at full moon, and pass on to its second quadrature, where it will be 240,000 miles in advance of the earth; and then, in another half lunation, it must fall back, relatively, twice 240,000 miles to the same relative position from which we started with it.

And it is well to notice that this motion, apparently a circle round the earth, is really, in relation to the sun and in a long period, a series of alternate small undulations on each side of the earth's orbit, the longer ones being on the outside and the shorter ones on the inside, and the difference between their chords being nearly a million of miles; and while the moon is making this slow motion in relation to the earth, it advances near fifty millions of miles with the earth along its orbit round the sun. No other satellite moves so slowly, because no other is so little held by the attraction of its primary compared with that of the sun, which is 2.2 of the earth's, while, in relation to most other satellites, it is measured by thousandths, and in relation to only the two outer satellites of Saturn and Uranus does it rise above hundredths.

Take also the earth in its revolution round the sun. Its apparently circular orbit changes entirely when we take into account the sun's motion in its own orbit, said to be 150 millions of miles a year. If we start with the earth at its vernal equinox, it is 95 millions of miles in the rear of the sun, and in six months it moves forward to a position as far in advance, with the chord of its curve elongated 75 millions of miles by its motion with the sun. Passing its autumnal equinox to the inside of the sun's orbit, it sweeps back in another six months to its original relative position in the rear of the sun, and yet, having moved with the sun, it is found 150 millions of miles in advance of the position whence we started with it, and 115 millions in the rear of its position six months before, and its real annual orbit turns out to be an immense scollop, the loop of which on the sun's orbit is 115 millions of miles wide, the motion being really retrogressive during the second half of each year, and the length of its real journey in absolute space along its real orbit being near twice as great in the first half of the year as in the second half.

Thus all the planets and satellites have orbits consisting of very long

curves in the outer half of each revolution, connected together by short curves, some of them loops, in the inner half, and perform journeys immensely greater in absolute space in one than in the other. Surely it is impossible that these alternations of fast and slow motion can be accounted for by the single transient impulse given to each body at the start of the system. Surely we are required to find some constant abiding or constantly renewed force to account for such phenomena. What is it?

Where shall we find the force that prevents the consolidation and centralization threatened by the force of attraction? Of course we must find the answer in the phenomena of our solar system, that being the only one of which observation gives us any competent knowledge. Philosophy cannot go back to find it in the phenomena of creation, for that is not phenomenon for us, and therefore that process must ever remain transcendental to us, until we can witness it in some other system and transfer it by analogy to our own; the only way in which we can know anything of our own personal origin.

All these regulated and phenomenally self-sustaining movements have a strong analogy to life, though we do not conceive of life as a mere property or movement of matter in a system. Phenomenally and statically it is the normal interaction of all the particles of a given system that sustains and constitutes its life; though this definition cannot deter us from our natural seeking after the dynamics of the system, the forces and causes of this interaction. And so it is in our investigation of the solar system.

We have given to us, by observation of it, over one hundred cosmical bodies, each revolving about some other, which is also moving, and each having a force attractive of all others, and moving at such a distance and with such velocity that it is neither drawn to nor driven from its central body. We find therefore a permanent system of moving and attracting bodies, and for convenience in the study of this fact, we analyse it into two forces—bodies attracting and bodies moving, or, more simply into attraction and motion; though in physics and apart from bodies, these last are nothing but abstract ideas, being the mental instruments by which we handle the actual and concrete forces—bodies moving and attracting.

We infer that the forces of attraction and of motion balance each other so as to prevent both consolidation and dissolution; but neither, by itself, can maintain the system. Without seeking after the origin of these motions, it is enough for us, that, at any given instant of time, they balanced the force of attraction. Then the question arises—how is this system of motions maintained? Or more definitely thus—given a satellite revolving round a planet, itself round another body and it round another, how is the motion of the satellite maintained? What is there in the forms and forces of this system that constantly restores the proper degree of motion in the satellite amidst the retardations and accelerations which we have discovered?

The readiest illustration of the system is the motion produced when a

ball at the end of a string is swung from right to left around one's hand as one moves rapidly in the same direction around a path, composed of a series of curves or loops all turning to a common centre. If we analyze the motion of the ball, we find that, while, relatively to the hand, it is nearly circular, it really performs a very complex figure relatively to the centre of the greater circle in which the person moves, passing an equal or nearly equal portion of time on each side, and yet with a much shorter path and slower motion on the inner, than on the outer side; this difference being always increased with the rapidity of the motion in the larger circle and with the slowness of that in the smaller one. Thus the ball's motion may resemble that of the most remote planets or of our moon, consisting of a series of alternate long and short undulations, or that of the other planets and satellites, being a series of scollops or of alternate long and short curves looping into each other.

And while the ball is performing this motion, the hand does not keep on the line of the greater circle, but performs a series of motions alternately on each side of it, corresponding in form to the larger ones of the ball; and in this its motion resembles the small motion of the planet on its orbit, no planet having a satellite ever moving exactly along its theoretic orbit.

Let the moving ball represent the tangential, and the string the attractive force of the whole movement, and we have the statical condition of a balance of forces. But the tangential force, not being a *vis viva*, would soon give way to the other, if there were no recuperative arrangement in relation to it, and our illustration directs us to the actual arrangement. It consists of the constant motion of the central force. This is the key to the dynamics of the system: attraction by a constantly and peculiarly moving central body. Of course both bodies exert this force, though that of the central body is always immensely greater than that of the other: it is all one force acting along the same line.

This is the moving force that maintains the motions of its dependent bodies, and we find no repulsive force; though, for distinctness of thinking, we find it necessary to analyze the motion into radial and tangential elements, and consider these as representing two colliding forces. A system of forces is an essential element of every system of actual things, and there can be no motion within the system except what is given or upheld by the very forces that constitute the system, supposing of course no interference from without.

This is a force constantly acting, and moving as it acts, ever changing the position whence it acts and therefore the direction of its action; always departing from its point of action and therefore from the very results which its action in each moment tends to produce; always fluent in itself and always fluent in its effects.

As the planet sweeps, with its unsteady rythm of undulations, along its own series of scollops or loops, called its orbit, the satellite sweeps tangentially throughout that orbit; and thence, obeying the attractive force of the planet without giving up the force of its own motion,

bends its course into a curve which carries it out far beyond the planet's orbit, and, still further obeying the same force, it hastens forward with it until, passing in advance of it, its speed is checked by the same force, and it swings round through the same orbit and is, by the force of its own motion, carried far inside of it, where it reduces its speed, because, by reason of the forward motion of the planet, this motion can there make but little draft upon it, and waits until the planet again passes in advance of it and renews its force, when it rises again through the orbit, and repeats the same series of movements. Here then is the force that corrects all the irregularities of motion in the system, checks all accelerations and revives from all retardations. By analogy to the term central force, I venture to call it the orbital force of cosmical motion, because it proceeds from a body moving in its orbit. I think I have said enough to present the subject sufficiently to those who desire to think about it.

But it is impossible to stay the mind at this point; it must seek to find the next link backwards in the chain of causes. If thus planets move and maintain the motions of their satellites, then the sun must move in a similar way to maintain the motions of the planets; and we have evidence that it is so. And the sun also must have its moving centre, and so on indefinitely. This too we may suppose, though we have no direct evidence of it.

This ought not to surprise us; for no where, in the acquisition of knowledge, does observation carry us back to the Great Centre of all causes, nor often to very remote ones; and yet it is a natural process of our philosophic faith to reach out and assume a cause for every thing, and we do assume it in harmony with the character of the effect; physical or spiritual, moral or intellectual, personal or impersonal, according to its demands. Thus only can we fill up the inevitable gaps which experience and observation leave to be supplied in every investigation; and thus we are continually led back to the assumption of causes, principles and ideas that can be, as it were, felt by the mind, and which yet transcend all the definitions and manipulations of deductive logic. All our abstractions are natural reachings of the mind towards the absolute in some special aspect of it, and often we make thereby very valuable acquisitions.

And certainly it is not desirable that we should have capacity to start from first causes and deduce from them all the systems and events of the universe; for our happiness depends, not upon the reach of our minds, but upon their continued and proper growth; and this can be only a gradual process, rising from the observation of things and events and from a study of their dynamics to proximate causes, and from a co-ordination of these to more remote and higher ones, without any supposable end to the means or to the functions of our progress. A mind whose chief function is growth cannot commence with the condition to which it aspires, for then it could have neither growth nor aspiration.

And it is not chargeable as a vice, that we are compelled to postulate

forces beyond the special system which we are studying, analogous to those found in it, nor even if we postulate others within it. Every system of actual things requires such postulates to connect it intellectually with some higher system, or to furnish it with at least a provisional foundation, or to give completeness to its structure; and especially every phenominally self-sustaining system requires us to postulate and then seek within itself the forces by which it is maintained, besides its initial force proceeding from without. Thus every class of plants and animals has within itself the forces by which the creative act is maintained, though always dependent on the larger system of the universe; and the science of physiology is founded on this assumption.

In the study of language, having no history of its origin, we may assume that it was a gift by God to man; but, thus received, it could be but very feebly maintained as a mere treasure of the memory, and in the very form in which it was bestowed; and, in order to account for its continuance in all its varieties, with its degradations, restorations, additions and improvements, even with a fundamental identity of structure, we must postulate other mental forces, which, with memory, constitute our faculty of language, and then proceed to seek them out.

And so it is with law, government and religion, with all their rules, forms, rites, symbols, and principles of faith and conduct. Their origin may be beyond our reach; but we are not, for this reason, prevented from learning that memory is the mere servant of other faculties in maintaining them through all the changes which they, with man, undergo, and that it is a prominent function of our life to work out our own development of them, and to improve by doing so.

I now venture to suggest very generally and briefly some of the consequences that would seem to follow from the admission of the dynamical views here presented.

1. We must give up Sir Isaac Newton's mode of accounting for the elliptical form of cosmical orbits. I expressed this in August, 1860, to the Academy of Science and Arts at Pittsburgh, founding it merely on the fact that all cosmical centres are themselves moving. The foregoing considerations now make this result more obvious.

2. There are many forms of cosmical motion, treated as inequalities, which are as normal elements of the special or partial system in which they are found as are the eccentrics on the axis of a steam engine, and they are not abnormities or disturbances produced by the forces of bodies out of the system, though they may themselves, in some cases, be disturbed, exaggerated, obliterated or even reversed by such forces. I venture to name as belonging to this class, the moon's annual equation, the motion of apsides, variations of eccentricity and of major axis, and also the recession of planetary nodes, including the procession of the equinoxes

3. This orbital force requires great inequalities of relative as well as of absolute motion, and presents a very obvious explanation of the inequalities of the moon's motion as the earth, with its unequal velocity,

passes from perihelion to aphelion and back. Considering the real form of the moon's orbit in relation to the sun and to the earth and its distances from each, and the very small angles of eight minutes formed at the sun by the radius of its orbit at its quadratures, and of one minute at its syzigies, it does not seem that such inequalities can be mere disturbances of the moon's orbit by the central force of the sun.

4. This force would seem also to require a change in the mode of calculating cosmical disturbances. Instead of starting us from the basis of an ideal ellipse, depending on a transient force of unknown quantity, it gives us real ones depending on a constant force for each case, which may be calculated. The forms thus given must be the true normal forms of the respective orbits, and departures from them must alone be treated as disturbances.

I have only to add that, however unsatisfactory it always is to eliminate any element of a system by declaring it anomalous, yet I do not see how this is to be avoided in relation to the satellites of Uranus, if the observations reported about them are accurate.

Stated Meeting, October 1, 1869.

Present, twenty-two members.

Prof. CRESSON, in the Chair.

A letter accepting membership was received from Linant Bey, dated Cairo, April 20, 1860.

An extract from a letter from M. Carlier to Mr. Durand respecting the Michaux Legacy was read.

An extract of a letter from Mr. Lesquereux to the Secretary respecting Mr. Schimper's Palæontologie Végétale was read.

Donations for the Library were received from M. Linant de Bellefonds Bey, the British Association, the London Geological Society, Mr. Gore, F. R. S., and the Boston and Montreal Natural History Societies.

The death of Dr. Dorr, member of this Society, at Germantown, Sept. 18, aged 73 years, was announced by Mr. Fraley.